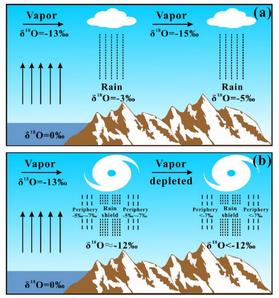
Isotopic signals in precipitation and water vapor during the Hurricanes Irma & Maria

Yan Yang[1], Alexandre Cauquoin[1,2], Kei Yoshimura[1] and Martin Werner[3]

1. Institute of Industrial Science, The University of Tokyo, Kashiwa, Japan. 2. Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan. 3. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Sciences, Bremerhaven, Germany.

Context and Objectives

- Powerful storms formed in the open Atlantic Ocean could become more frequent due to the global warming (*Murakami et al., 2020*)
- There is no isotopic model simulation for the hurricanes before in this domain



(*Xu et al., 2019*)

	Irma (2017)	Maria (2017)
Formation	8/30	9/16
Dissipation	9/12	10/2
Lowest pressure	914 hPa	908 hPa

	ECHAM6	IsoGSM
Nudged to	ERA5	ERA5
Horizontal resolution	~ 0.9°	~ 1.9°
Vertical layers	95	17
Time step	6 h	6 h

Research Objectives:

- To evaluate ECHAM6-wiso for such meteorological processes
- To investigate the isotopic characteristics of tropical cyclones in the Atlantic region
- To compare the modeled results from ECHAM6-wiso and IsoGSM
- To evaluate the influence of the moisture transport on the hurricane isotopic ratio

Hurricane Tracks

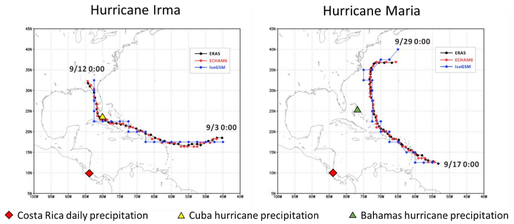


Fig. 1 Trajectories of Irma and Maria from ERA5, ECHAM6-wiso and IsoGSM and location of in-situ observation stations

- The hurricane's paths simulated by ECHAM6-wiso mainly follow the ERA5 ones
- The simulated paths by IsoGSM are slightly different due to the limitation of spatial resolution

Simulations VS Observations

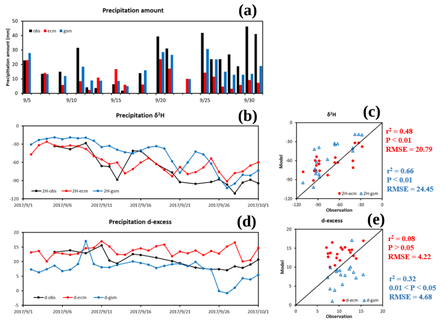


Fig. 2 Observed (black) and simulated (ECHAM6-wiso and IsoGSM in red and blue, respectively) daily precipitation amount (a), δ^2H (b,c) and d-excess (d,e) in Costa Rica in September

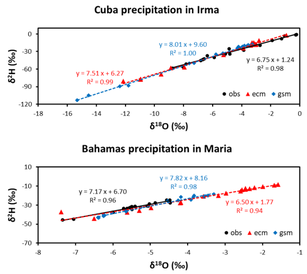


Fig. 3 In-situ observed and modeled isotopic content of precipitation during hurricane events

- ECHAM6-wiso and IsoGSM were able to simulate isotopic ratio, but may underestimate the precipitation amount

Isotopic Characteristic of Hurricanes

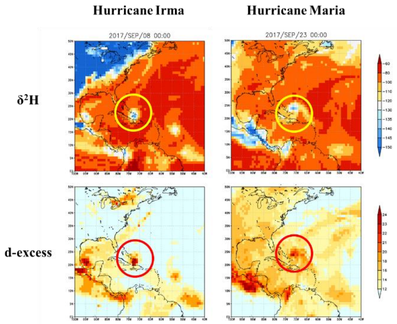


Fig. 4 δ^2H and d-excess of surface vapor simulated by ECHAM6-wiso at 9/8 00:00 for Irma and 9/23 00:00 for Maria

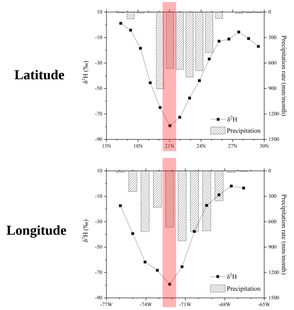


Fig. 5 Latitudinal and longitudinal sections of precipitation isotopic ratio and precipitation rate in the hurricane Irma at 9/8 00:00.

- High condensation efficiency of rainstorms and recycling of isotopically depleted vapor could lead to extremely negative δ^2H and a high d-excess in vapor and precipitation

Model Inter-comparison

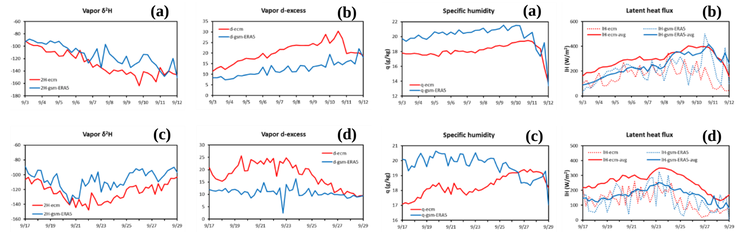


Fig. 6 Intercomparison of surface vapor isotope between ECHAM6-wiso (red) and IsoGSM (blue) in the center of Irma (a,b) and Maria (c,d)

Fig. 7 Same as Fig.8, but for surface specific humidity (a,c) and latent heat flux (b,d).

- Irma and Maria showed a different trend of δ^2H and d-excess in the last half period
- The d-excess simulated by ECHAM6-wiso was higher than IsoGSM
- The distinguishing spatial resolution of ECHAM6-wiso and IsoGSM may cause the difference of isotopic value

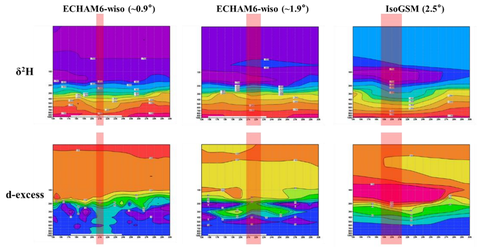
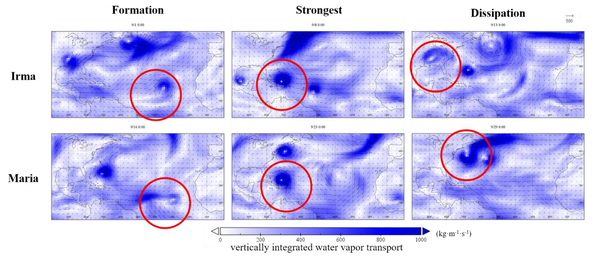


Fig. 8 The vertical structure of vapor isotope crosses the center of Irma at 9/8 0:00 for ECHAM6-wiso at a resolution of ~0.9°, ~1.9° and IsoGSM

Moisture Transport



- Moisture from low-latitude ocean surface was still transported to Maria , which caused an increase of isotopic ratio in the last half period

Fig. 9 Moisture flux from ECHAM6-wiso at 3 stages of hurricanes

Conclusions:

- ECHAM6-wiso is able to simulate the isotopic characteristics of tropical cyclone, but may underestimate the precipitation amount.
- The isotope ratios (δ^2H, $\delta^{18}O$) of vapor and precipitation decrease rapidly going toward the center of the hurricane, and the d-excess was higher in the center.
- The d-excess values simulated by ECHAM6-wiso were higher than IsoGSM, caused by difference in simulated specific humidity and latent heat flux between the two models. The spatial resolution also influenced the vertical structure.
- Moisture from low-latitude ocean surface was still transported to the hurricane Maria, which caused an increase of isotopic ratio of surface water vapor during the last half period of this hurricane.